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# Modeling for Removal of Nickel and Lead from Industrial Wastewater by Adsorption

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**Abstract**

*Heavy metals are stable and persistent environmental contaminants. They cannot be degraded or destroyed. The main anthropogenic sources of heavy metals are industries. The removal efficiency of heavy metals by preparing activated carbon from sugar mill sludge is determined. The carbon has been used as adsorbent. The experiment was carried out manually by batch process and column flow system. The results obtained are processed statically by developing a program to run in MATLAB software and the removal efficiency obtained through MATLAB processing was more than 90%. This experimental study has been carried out to develop an economical method of heavy metal removal, so that even small industries can adopt this method for their wastewater treatment and hence they can prevent the polluted water entering the stream. The results are provided in the requisite tabular as well as graphical forms.*

***Keywords**: adsorption, batch study, column study, MATLAB*

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## INTRODUCTION

### General

Heavy metals are natural constituents of the Earth's crust and are present in varying concentrations in all ecosystems. Heavy metals are stable and persistent environmental contaminants since they cannot be degraded or destroyed.

The main anthropogenic sources of heavy metals are various industrial sources, including present and former mining activities, foundries and smelters, and diffused sources such as piping, constituents of products, combustion by-products, traffic, etc. Heavy metals are also known to produce adverse effects on the environment and human health.

### Pollution due to Heavy Metals

Heavy metals include all metals with atomic number greater than 23 and specific gravity more than 5. Heavy metals and their compounds, unlike most of the other pollutants, occur naturally in the environment also [1]. Heavy metal pollution in the environment can originate from natural as well as from man-made sources.

The natural sources of heavy metal pollution are geological weathering and volcanic activities. Electroplating industries, battery manufacturing units are some of the man-made sources of heavy metal pollution. Heavy metals are toxic even at low concentration to humans and other living beings [2].

## LITERATURE REVIEW

### Adsorption with Activated Carbon

Organic compounds in wastewater are resistant to biological degradation and many are toxic or nuisances (odor, taste, color forming) even at low concentration. Low concentration metals are not readily removed by conventional treatment methods. Activated carbon has an affinity for inorganics and its use for inorganic contaminant removal from wastewater is widespread [3].

The larger surface area, a critical factor in the adsorption process, enhances the effectiveness of the activated carbon for the removal of inorganic compounds from wastewater by adsorption. The surface area of activated carbon typically can range from 500−1400 $m^2/g$ [4].

## MATERIALS AND METHODS

### Experimental Procedure

***Preparation of Sugar Mill Sludge-Based Activated Carbon***

Sugar mill sludge was collected and dried in an oven at a temperature of 170 °C for 24 h. It was then packed in an air tight cylindrical iron container with a completely sealed lid to prevent the entry of air during the process of charring. The sealed iron container was heated in a muffle furnace by slowly raising the temperature up to 600 ºC and maintained the same for 1 h. During this process, the sugar mill sludge was converted into charred coal. The activated carbon thus prepared was subsequently washed with distilled water, oven dried and packed in a polythene cover and kept in air tight container for further experimentation.

***Analysis of Nickel Using Atomic Absorption Spectrophotometer***

Atomic absorption spectrophotometer was used to analyse the initial and residual metal concentration after each and every experiment. This instrument is more accurate in analysing the heavy metals (Model GBC 902). Flame method was used for the analysis of metal and the flame used was air acetylene flame. To analyse, first the instrument was set at a wave length of 351.5 nm, slit width at 0.5 and l amp current at 4 mA. It was standardized with 20 ppm, 40 ppm, 60 ppm, 80 ppm concentration of metal solution. After calibration, the instrument was put in concentration mode. Then by aspirating the sample, the metal concentration will directly be evaluated by the instrument and was shown as digital display and the value could be printed by the printer.

### Adsorption Studies

The evaluation of sugar mill sludge-based activated carbon chosen for Nickel removal in this study has been done in batch reactor to assess the parameters influencing the adsorption process such as contact time, optimum dosage, adsorption isotherm, pH, initial concentration and to predict the approximate residual Nickel attainable [5,6].

***Batch Adsorption Experiments***

Batch reactors have been employed in these experiments where in predetermined quantities (150 ml) of desired concentration were agitated continuously with known weight of the sugar mill sludge-based activated carbon. The mixing arrangement was facilitated by wrist action shaker containing eight holders (reactors). After the contact time (5 min), 2 ml of sample was drawn from each of the eight reactors, filtered using a Whatman filter paper and was analyzed for its residual Nickel concentration. The same procedure was adopted for all batch studies to determine of optimum pH, optimum time adsorption, optimum sorbent dosage, optimum concentration and isotherm studies.

***Column Studies***

***Fixed Bed Column Adsorption System***

This type of system is most often used to treat large quantities of wastewater in fixed bed adsorption system. The continuous flow could be either in upward or down ward directions. Packed bed up flow carbon columns for full counter current operation are suitable only for low turbidity water, i.e., water having a turbidity of 2.5 JTU. Carbons finer than 8 × 30 mesh should not be used for up flow fixed beds because of clogging and high head loss problems. In liquid up flow operations, a portion of the adsorbent is usually removed periodically from the bottom and equal amount of regenerated solid is added to the top.

## MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation algorithm development data acquisition modeling, simulation, and prototyping data analysis, exploration and visualization of scientific and engineering graphics, application development, including graphical user interface building. MATLAB is an interactive system whose basic data element is an array that doesn't require dimensioning.

### Trend Analysis of Parameters

To study the pattern of trend of the parameters during the study period, the polynomial trend equation namely, cubic trend equation of the form, $Y = b_o + b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 \ldots$, where $b_i$'s (i =1,2,3,4) are trend coefficients and $b_o$ = constant, $t_i$ = *ith* time (i = 1,2,3…) is fitted and the results are presented below. The F-values indicate the overall significance of the trend equation fitted. The $R^2$ the coefficient of determination indicates that to what extent the trend coefficients are able to explain the variations of the dependent variables under study.

Polynomial trend equation Y = b0 + b1 t + b2t2+ b3 t3 + b4 t4,

Trend Eqn : $Y = 4.4822 + .0688\ t + 5.0408E\text{-}08\ t^2$

Trend Eqn : $Y = -.5506 - .0035\ t + .00034\ t^2 - 3.1465E\text{-}07\ t_3$

Trend Eqn: $Y = -5.2098 + .4806\ t - .0009\ t^2$

Trend Eqn: $Y = -.2652 - .0245\ t + .0112\ t^2 - 6.E\text{-}05\ t$

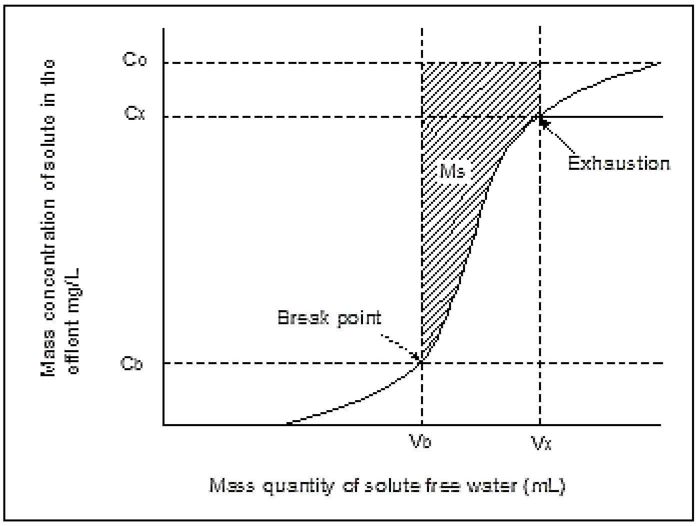
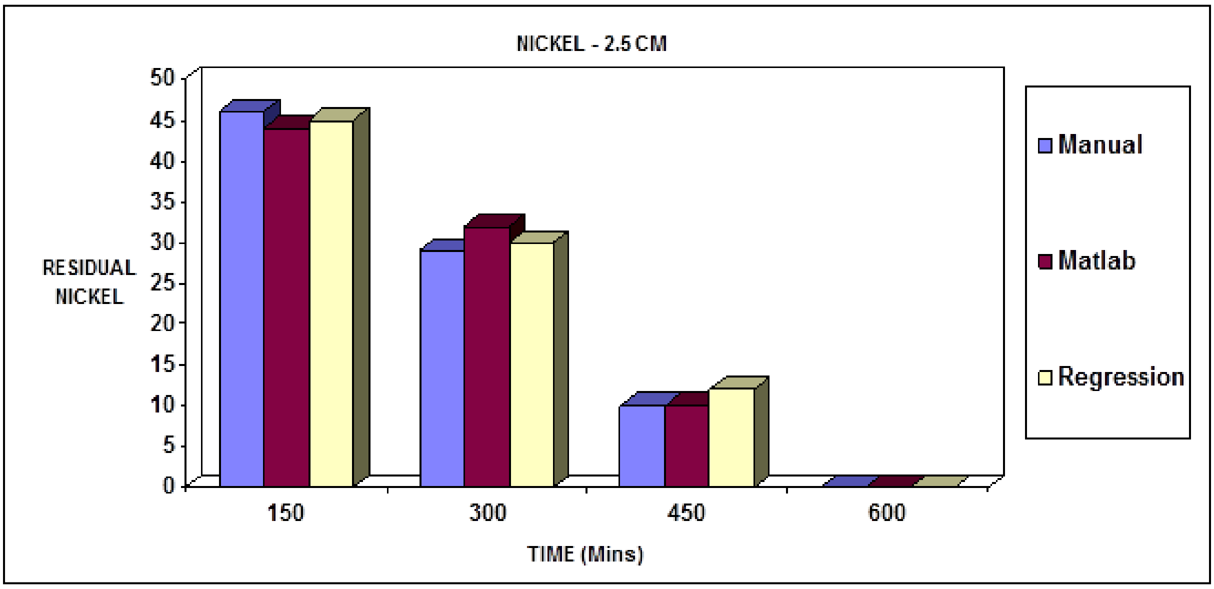



***Fig. 1:*** *Ideal Break through Curve in a Fixed Bed Adsorption System.*

***Table 1:*** *Trend Analysis for the Residual Concentration Model for Nickle 2.5 cm.*

| *Model* | $R^2$ | F | **Trend Coefficients** | | | | |
|---|---|---|---|---|---|---|---|
| | | | b0 | b1 | b2 | b3 | b4 |
| *Quad* | .992 | 2357** | –4.4822 | .0688 | 5.0408E-008 | - | - |
| *Cubic* | .998 | 3639** | –.5506 | –.0035 | .00034 | –3.1465E-07 | |

*** Significant at 1% level.*



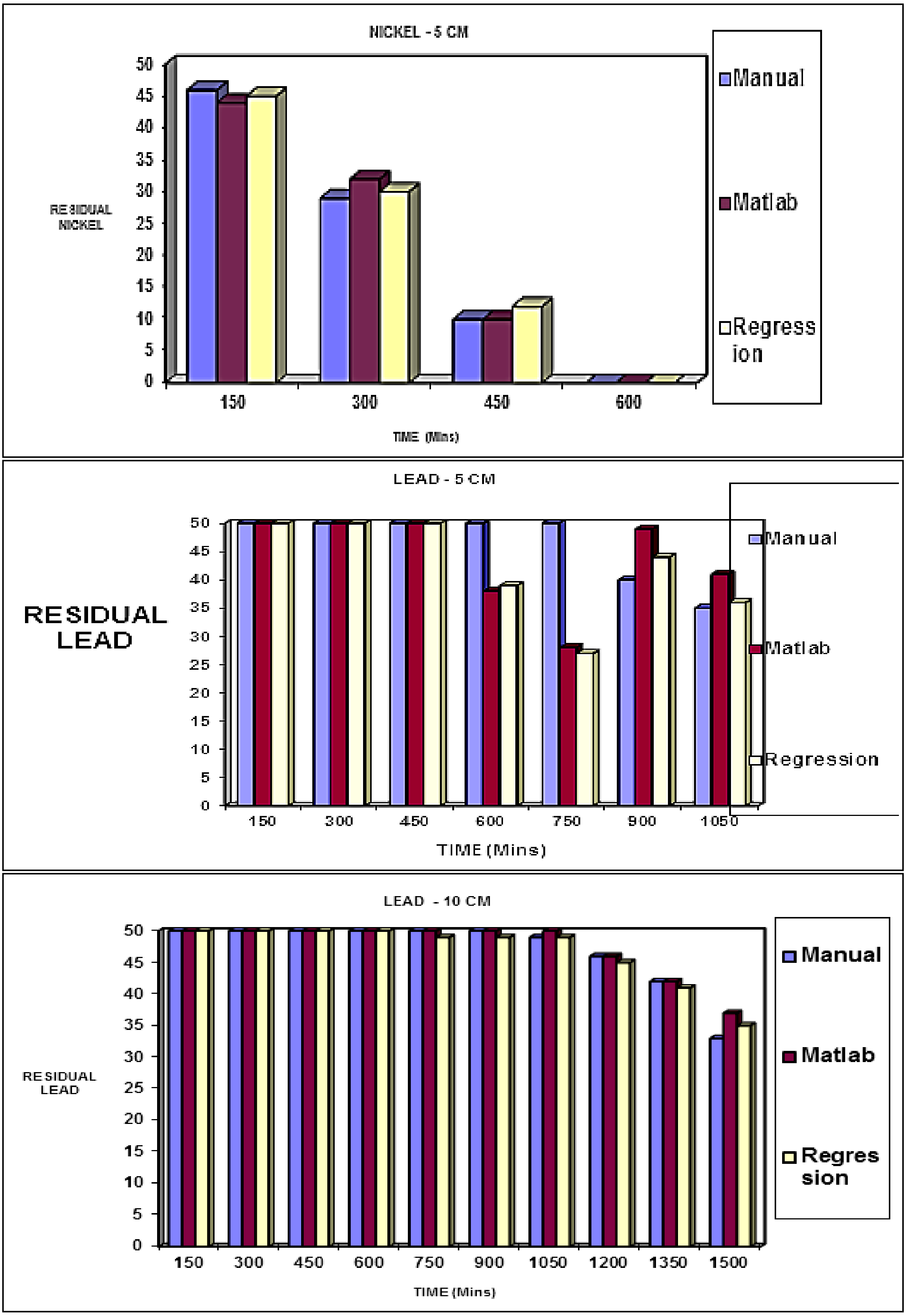



***Fig. 2:*** *Comparison Charts for the Results Obtained Manually with Those of MATLAB and Regression.*

***Table 2:*** *Model for Nickel 5 cm.*

| Model | $R^2$ | F | Trend Coefficient | | | | |
|---|---|---|---|---|---|---|---|
| | | | b0 | b1 | b2 | b3 | b4 |
| *Quad* | .988 | 4500** | –5.278 | .0329 | 1.48E-06 | - | - |
| *Poly* | .999 | 22271** | .422 | -.0098 | 7.37E-05 | –3.97E-08 | 5.85E-12 |

***Significant at 1% level.*

## RESULTS AND DISCUSSION

### Comparison Charts for the Results Obtained Manually with Those of MATLAB and Regression

The following charts are the results of the percentage removal of various metals for various bed depths of carbon [Figures 1 and 2] and [Tables 1 and 2].

## CONCLUSION

To determine the removal efficiency of heavy metals such as Nickel, Lead and Cadmium from the aqueous solution, the activated carbon prepared from sugar mill sludge was used as the adsorbent and the removal efficiency was noted at various time intervals and at bed depths of 2.5 cm, 5 cm and 10 cm. The data generated using the experiments were utilized in developing a program in MATLAB. Using the program for a specific metal at any bed depth and at any time can be determined.

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